HEALTH AND HUMAN SERVICES

Dust in the Wind

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In 1997, while a professor at the University of California at Berkeley, Kris Pister proposed a project to deliver sensing, computing and networking in a millimeter-sized package. The project, called Smart Dust, was funded by DARPA the same year.

The idea was to make low-cost, battery-operated wireless sensor networks to drop over a battlefield or other areas of interest, or place them quickly and easily in a variety of buildings and structures to evaluate the situation, said Pister, who is president and CEO of Dust Inc.

"You can monitor when people or vehicles go by, you can track things, whether they're enemy combatants or civilians -- there are all sorts of great things you can do if you've got the sensors to do it," he said. "It's all stuff you can do today if you spent the time and money to wire it all up, but you don't have that luxury in a battle or in a foreign country you're about to have a battle in -- you just can't get in there with a wired system."

Beginnings

A Smart Dust "mote" is a sensor-processing node -- a millimeter-sized point in a network that observes and records its surroundings. Information these motes collect varies depending on what you want to observe, said Steven Glaser, associate professor for the Department of Civil and Environmental Engineering at UC Berkeley.

"It has a microcontrollor, two-way radio, buffer memory and so on and so forth, and it's dynamically reprogrammable, so you can change what it can do at a later time," he said. "It's a smart device; they have an operating system that allows devices to

talk to each other, and [transfer] data without the interference from an outside boss, so it's a peer-to-peer network."

Smart Dust uses ad hoc networks, Glaser said, which means the devices set the network up themselves on the fly, and the network structure changes through time.

The network can also be set up arbitrarily, Glaser added, and because the motes or nodes are autonomous, they self-assemble into a network. Intermediate nodes help distant nodes reach the mother unit, which controls the sensor data, and is connected to a PC, known as the base station.

The sensors use an open source software program for wireless networks called TinyOS to talk to each other. David Culler, a professor of computer science at UC Berkeley who directs the Intel Research laboratory at the university, wrote TinyOS.

When a new technology is announced, people tend to doubt its reliability until it is proven, which is what Culler, Glaser, Pister and everyone else with their hands in the Dust, are working on. Initially testing in the environment made the most sense because the nodes could be dispersed and collect data without affecting anyone.

"How do you go through the steps and develop a trust with new technology?" Culler said. "The natural place to start was the environment. For one thing, it doesn't move."

Glaser and his graduate students, in conjunction with the Lawrence Berkeley National Laboratory, are measuring humidity in the nuclear waste repository being planned in Yucca Mountain, Nev. The device traditionally used to measure humidity in the repository is large and emits a lot of heat, Glaser said, which changes the humidity.

Because Smart Dust is so small, it can operate for long periods without wires and

send data from locations where a large device wouldn't go. It was the perfect candidate. Glaser also has upcoming projects in Israel and China.

So far, the largest number of motes dispersed in an area is several hundred, Culler said, adding that development to make the networking easier is ongoing, and assembling the networks is still a fair amount of work.

Smart Dust motes are considered cheap -- a few hundred dollars each, Glaser said, but prices will lower because right now they're still considered research devices. As they become commercial, the cost will lower considerably because much of the cost is development.

"The sensors can range -- let's say for vibration -- from $5 apiece to $1,000 apiece, depending on how sensitive you want them for what you need," Glaser said. "If you're looking at very strong earthquake response, and you're not interested in small tremors but real earthquakes, then the $5 piece works just fine."

Branching Out

Not only can Smart Dust be used in the environment, it can be used in a variety of other arenas as well.

"We're going after the building automation market -- that's one of our first," Pister said. "Industrial automation and building automation are two huge potential markets. In building automation, it's things like lighting control, heating, ventilation and air conditioning, energy management. Buildings are chock-full of sensors today, and they're all wired. It's very expensive.

"Everybody's got a budget, and a piece of that is an energy budget," Pister said. "We're working with some of the energy-management companies to help [the federal government] monitor energy use, which is the first step in reducing it."

This type of system is in active development, Culler said, adding that Smart Dust's potential is allowing people to view things in a different way.

"This gives the ability to monitor what's going on in a space," he said. "It gives a different kind of scope. Like a microscope allows you to see tiny things, Smart Dust lets you perceive what's going on in an environment in a great amount of detail."

As of fiscal 2000, the military base in Fort Bragg, N.C., spends $29 million per year on energy, $23 million of which is for electricity, according to the *Fort Bragg Integrated Strategic Environmental Plan* published in June 2001. Because the base only has four power meters, Pister said, it has no idea where that energy is going.

"Until you know how you're using the energy, it's difficult to figure out the best way to reduce your energy consumption," he said.

Smart Dust can also meet specific military needs, commercial factors, government needs outside the military and mundane things like monitoring incoming and outgoing mail in a post office, where a large number of objects are moving around, Culler said. Smart Dust can also be used for asset management, to expand emergency personnel and by fire departments.

"You could toss a few into a room to assess the situation, see if there are toxins in the air, unusually high temperature or humidity," he said.

In homeland security, the potential uses of Smart Dust include surveillance, port tracking and container security.

Future Tense

As Smart Dust matures, pricing will go down and reliability will go up, which should

increase demand for the technology, Glaser said.

"There are problems we haven't even thought of because, in general, measuring things is expensive now," he said. "So if it becomes cheap -- I mean now, what do people do? They look for ways not to have to measure it because it's too much money. If it's cheap enough, what can we measure? People get pretty creative."

The practical application of Smart Dust today, scattering the motes to collect information, will most likely not be its primary mode of use, Culler said, noting that the more likely application is to see them embedded in manufactured items -- leading to sensors being embedded in tiles, the ceiling, walls, furniture, or just about anything else in a house or building.

"If you went back 100 years, electricity was a big deal," he said. "Now we take it for granted. I think this technology will become more a part of information interface, receding into a substrate."

The increasing emergence of Smart Dust will bring social and legal implications, Culler observed.

"With this different information, what are privacy implications?" he said. "We have to address all kinds of questions about certification, liability, what's the regulatory regime? What's it mean for the FCC?"

Pister is also concerned with social implications and wrote Sensor Networks in 2010, in which he addresses what those implications might be. He also said it will be interesting to see how society deals with all the information Smart Dust will bring.

"What are your responsibilities when your cell phone rings and it's your neighbor's pool calling to tell you that little Johnny has fallen in, is drowning and can you please get him out?" Pister said. "There's an obvious answer there, but what if it's their cat

that's fallen in?"

Concerns over personal privacy must also be addressed head-on, he said. "It's not going to be overnight that everybody's snooping on everybody else. We will have time to make sure we do it right, and make sure we get the tremendous benefit from this technology without getting the problems."

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